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(54) Control device for a linear oxygen sensor

(57) Control device (1) for a linear oxygen sensor (2) located in the exhaust pipe (3) of an internal combustion engine (4), the sensor (2) having a diffusion chamber (13) capable of receiving part of the exhaust gases, a first (11) and a second (12) electrolytic cell, the first of which is controllable with respect to current, and a reference chamber (14) capable of containing a specified percentage of oxygen; the sensor (2) can be one of two different types (2a, 2b), according to whether the oxygen in the reference chamber (14) is fed in through a connection to the atmosphere or is generated by polarization of the second cell (12); the device (1) having an operating unit (10) and a controller (8) interacting with the operating unit (10) to regulate the current (Ip) sent to the first cell (11) according to the instantaneous difference between the percentage of oxygen present in the diffusion chamber (13) and that present in the reference chamber (14); the controller (8) being provided with a polarization circuit (31) which can be activated selectively to polarize the second cell (12) and to generate oxygen in the reference chamber (14); and the operating unit (10) having a serial line (20) for operating and programming the controller (8) by means of which it can match the controller (8) to the type (2a, 2b) of sensor connected.

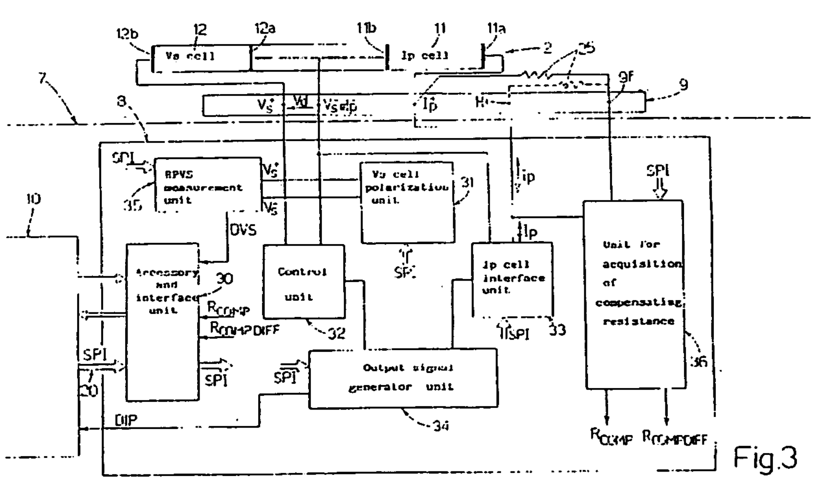

Fig.3

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tion engine, the control device comprising a controller of the sensor capable of exerting a control action on the sensor to generate at the output a signal representing the ratio of the exhaust gases: the sensor comprising at least one reference chamber capable of receiving a specified percentage of oxygen, and being one of at least two types which differ in the way in which the reference chamber receives the oxygen; and the control device being characterized in that the controller comprises programmable control means and in that it comprises an operating unit capable of operating and programming the said control means to match the controller to the type of sensor to which it is connected.

[0014] Conveniently, the control device for the sensor, where the sensor comprises a diffusion chamber capable of receiving the exhaust gases and a first and a second electrolytic cell sensitive to oxygen ions, the first of these cells being controllable with respect to current, is characterized in that the said control means comprise a feedback circuit capable of regulating the current sent to the first cell in accordance with the difference between the percentages of oxygen present in the diffusion chamber and in the reference chamber; the said feedback circuit comprising a means of generating the said output signal in accordance with the current sent to the first cell; the controller being connected to a compensating resistance capable of compensating the losses of the said sent current, and comprising an acquisition circuit capable of acquiring the value of the compensating resistance; the operating unit being capable of correcting the output signal of the controller in accordance with the acquired value of the compensating resistance, to generate a corresponding output signal which is truly representative of the ratio of the exhaust gases and which is independent of possible changes in the compensating resistance.

[0015] The control device is thus capable of compensating the losses of the driving current, by always using the acquired value of the compensating resistance. This ensures the generation of an output signal which is truly representative of the ratio of the exhaust gases and is independent of possible changes in the compensating resistance.

[0016] The present invention will now be described with reference to the attached drawings, which illustrate a non-restrictive example of its embodiment in which

- Figure 1 shows schematically a device for controlling a UEGO sensor, made according to the principles of the present invention;
- Figures 2a and 2b show schematically corresponding types of UEGO sensors used at present in internal combustion engines;
- Figure 3 is a functional diagram of a controller forming part of the device shown in Figure 1;
- Figure 4 shows a first functional unit forming part of the controller in Figure 3;
- Figure 5 shows schematically a second functional unit forming part of the controller;
- Figure 6 shows schematically three functional units forming part of the controller;
- Figure 7 shows the graph of two possible output characteristics of the controller;
- Figure 8 shows a diagram of a sixth functional unit of the controller; and
- Figure 9 shows a diagram of a seventh functional unit of the controller.

[0017] With reference to Figure 1, the number 1 indicates, as a whole, a control device for a UEGO sensor 2 of a known type, which can be located in the exhaust pipe 3 of an internal combustion engine 4 to supply information on the stoichiometric composition of the combustion gases, and ultimately on the A/F (air/fuel) ratio of the mixture supplied to the engine 4.

[0018] In the illustrated example, the sensor 2 is located before a catalytic converter 5 capable of eliminating the polluting substances present in the combustion gases before they are emitted into the environment. In a variant which is not illustrated, the sensor 2 could be fitted after the catalytic converter 5 to supply information on the stoichiometric composition of the exhaust gases leaving the catalytic converter 4.

[0019] The control device 1 comprises a control unit 7 (shown schematically), which is responsible for the overall control of the engine 4.

[0020] The electronic control unit 7 comprises a controller 8 of the sensor 2 which is connected to the sensor 2 by a connector 9. As is specified more clearly below, the controller 8 is capable of controlling the sensor 2, and is capable of processing the information obtained from the sensor to generate at the output a signal DIP correlated with the quantity of oxygen present in the exhaust gases and, ultimately, with the A/F ratio.

[0021] The control unit 7 also comprises an operating and processing unit 10, which has the double function of operating and programming the controller 8 and processing the information from the output of the controller 8. In particular, the unit 10 is a microprocessor unit capable of processing the DIP output signal of the controller 8 to generate a signal Vout, which is proportional to the quantity of oxygen present in these gases, and is converted, in a known way, by the control unit into a parameter λ indicating the ratio of the exhaust gases.

[0022] According to the present invention, the controller 8 (described below) has the distinctive characteristic of being capable of controlling UEGO sensors of different types. At the present time, motor vehicles are fitted with two types of UEGO sensor, which are illustrated schematically in Figures 2a and 2b and which, while they have many elements in common, differ in respect of some structural elements.

[0023] The two types of UEGO sensor will be described below, using the convention of indicating the first type of UEGO sensor with the reference 2a (Figure 2a), indicating the second type of UEGO sensor with the ref-

[0037] The nominal value of the compensating resistance 25 is specified on completion of the manufacture of the sensor 2, following functional verifications conducted to test the efficiency of the sensor.

[0038] According to the present invention, the controller 8 is made in such a way that it can carry out the control operation both in the case in which the resistance 25 is connected between the terminals 9a and 9f and in the case in which the resistance 25 is connected between the terminals 9d and 9f. As will be indicated below, this is because the controller 8 has a circuit for acquiring the value of the compensating resistance 25 which is capable of storing the value of this resistance, so that the DIP signal correction operations are always carried out with the same stored value of the resistance, independently of the real value of the physical resistance, which is known to be subject to thermal and/or atmospheric stresses capable of changing its nominal value.

[0039] The controller 8 will now be described in detail with reference to Figure 3.

[0040] The controller 8 comprises seven functional units, indicated by the reference numbers 30, 31, 32, 33, 34, 35, 36 and interacting with each other.

[0041] The functional unit 30 is capable of forming an interface between the controller 8 and the control and processing unit 10, and, as will be described, acts as an accessory unit to the other units. This is because the unit 30 not only supplies the other units with the information from the unit 10, but also provides them with physical values (for example, reference currents) which will be used within the units themselves.

[0042] The functional unit 31 is a unit which can polarize the sensing cell 12 of the sensor 2 in a selective way if the sensor is of the type shown in Figure 2b, in other words if the cell has to be polarized for self-generation of the oxygen in the reference chamber 14. In other words, depending on the type of sensor 2 which is connected to the controller 8, the unit 10, through the serial line 20, causes the unit 31 to polarize the cell 12 (sensor 2b), or keeps the polarization of the cell 12 disabled (sensor 2a).

[0043] The unit 32 is a control unit for the sensing cell 12 of the sensor 2, and is capable of processing the signal Vd at the terminals of the cell 12 to execute the said feedback control action, and to supply at the output a control parameter VAD which identifies the pumping current Ip to be sent to the pumping cell 11.

[0044] The unit 33 is capable of forming an interface with the pumping cell 11, and in particular is capable of controlling the current Ip according to the result of the processing operation carried out by the control unit 32.

[0045] The unit 34 is capable of generating the output signal DIP according to the result of the processing operation carried out by the control unit 32, and therefore, ultimately, according to the current strength required to maintain stoichiometry in the diffusion chamber 13. In other words, this unit 34 is capable of carrying out a kind of measurement of the pumping current Ip to supply the signal DIP at the output, and, as will be shown subsequently, is capable of being configured by the unit 10 in such a way that the signal DIP represents the ratio of the exhaust gases in a programmable and modifiable range of values. This means that the controller 8 generates an output signal DIP which, in a specified voltage range (e.g. 0-5 volts), can represent the variations of the ratio at discharge relative to a range of amplitude which is also programmable according to the requirements in terms of resolution.

[0046] The unit 35 is a unit capable of measuring the internal resistance RPVS of the sensing cell 12, the value of this internal resistance RPVS being indicative of the temperature of the sensor and being used to control the heating element of the sensor 2, in other words to regulate the current sent to the heating resistance 15 (Figures 2a, 2b).

[0047] Finally, the unit 36 is capable of executing the said operation of acquiring the value of the compensating resistance 25 which must be connected between the two terminals of the connector 9 (see Figures 2a and 2b). In other words, this unit 36 is capable of enabling the operating unit 10 to sample and store the value of the compensating resistance 25 in such a way that the unit 10 can always correct the signal DIP with the same parameter, thus compensating for the said losses of the driving current Ip of the cell 11. This acquisition takes place independently of the configuration of the connection of the compensating resistance 25 to the connector 9 (see Figures 2a and 2b).

[0048] The units 30, 31, 32, 33, 34, 35, 36 forming the controller 8 will now be described in detail with reference to Figures 4 to 9.

[0049] The unit 30 (Figure 4) has a power supply circuit 40 of a known type, which interacts with the operating unit 10 to receive a plurality of signals (e.g. battery voltage, voltage stabilized at 5 volts, and earths), and which is capable of supplying the power supply voltages and the earth references for the other units 31 to 36.

[0050] The unit 30 has an oscillating circuit 41 of a known type, capable of supplying at its output a clock signal BT which is used by the units which have to carry out time-based measurement or synchronization (for example, the said unit 34 for measuring the internal resistance RPVS of the cell 12).

[0051] The unit 30 is also provided with a current generator circuit 42 (of a known type), which is capable of generating a stable and precise reference current IREF, and which has the function of making it available to the other units to enable them to carry out the operations associated with them.

[0052] Finally, the unit 30 has two further circuits, indicated by the reference numbers 43 and 44, of which the circuit 43 forms the serial interface 22 of the controller 8, and is capable of converting the codes received from the microprocessor 24 into signals SPI for operating and programming the other units 31 to 36. The circuit

ing to which the driver circuit 73 sends the current Ip in order to regulate the mechanism for draining oxygen ions from the diffusion chamber 13 to the external environment (or vice versa) in an attempt to establish stoichiometry in the chamber 13.

[0064] In this way, a feedback control system which tends to cancel the error signal VERR is provided. In this feedback control system, if the exhaust gases entering the diffusion chamber 13 are derived from the combustion of a lean mixture, the signal VERR is greater than zero, and the PID controller operates the driver circuit 73 in such a way that a current Ip capable of generating a flow of oxygen ions from the chamber 13 towards the external environment is sent to the cell 11. Thus the feedback control system tends to return the chamber 13 to a stoichiometric state. Conversely, if the exhaust gases have a low oxygen content, in other words if they are derived from the combustion of a rich mixture, the signal VERR is less than zero, and the PID controller operates the driver circuit 73 in such a way that a current Ip capable of generating a flow of oxygen ions from the exterior towards the diffusion chamber 13 is sent to the cell 11. Thus the feedback control system tends to return the chamber 13 to a stoichiometric state.

[0065] The interface unit 33 connected to the pumping cell 11 also has a protection circuit 74 capable of preventing the voltage at the terminals of the cell 11 from exceeding a specified threshold value, beyond which the sensor 2 may be damaged. The circuit 74 is enabled by the operating unit 10 through the signals SPI.

[0066] According to the illustration in Figure 6, the unit 34 generating the output signal DIP of the controller 8 has a differential voltage amplifier 80, which is connected to the terminals of the sensing resistance 72 to measure the voltage drop across it and, consequently, to measure the pumping current Ip supplied to the cell 11.

[0067] According to the present invention, the amplifier 80 is a programmable gain and offset amplifier, and is capable of amplifying the input voltage for values programmable by means of the signals SPI. The output signal DIP of the controller 8 is present at the output of the amplifier 80, and this signal DIP is therefore a function of the strength of the current which is applied to maintain stoichiometry in the diffusion chamber 13. Since the gain and offset of the amplifier 80 are programmable, it is possible to measure currents Ip which have different dynamic characteristics, at different resolutions. This means that the controller 8 is capable of providing an output signal DIP which, in a predetermined range of voltages (e.g. 0 - 5 V), represents the variations of the ratio in the exhaust over a programmable range of values which can be modified according to requirements.

[0068] Figure 7 shows two possible graphs of the characteristic expressing the output signal DIP as a function of the strength of the pumping current Ip, these graphs being obtained with different gain and offset values of the amplifier 80.

[0069] Since the precision required in the measurement of the current Ip is very high, the unit 34 also has a calibration circuit 81 for the amplifier 80, for evaluating the errors introduced by the amplifier 80. This calibration circuit 81 is also activated by the operating unit 10 by means of the signals SPI, and, when activated, short-circuits the inputs of the amplifier 80 and connects them to the offset voltage. In this way, the measurement of the output of the amplifier 80 provides information on the measurement errors.

[0070] The unit 35 for measuring the internal resistance RPVS of the sensing cell 12 will now be described with reference to Figure 8. The internal resistance RPVS is measured by forcing a known reference current in the cell 12 and measuring the voltage drop across the terminals of the cell 12.

[0071] For this purpose, the unit 35 has a differential amplifier 85 whose inputs are connected to the electrodes 12a and 12b of the sensing cell 12 in such a way that the voltage drop Vd across the terminals of the cell 12 is present between them. The output of the amplifier 85 is connected to a sampling circuit 86 (in the form of a "Sample & Hold" circuit), whose output represents the said signal DVS at the input of the multiplexer 44 of the unit 30. The unit 35 also has a current generator circuit 87 connected to the electrode Vs+ of the cell 12 and capable of being operated by the unit 10 (by means of the SPI signals) to generate a reference current in the sensing cell 12. In particular, the reference current is obtained from the current IREF made available by the generator 42 of the unit 30, and its strength can be regulated according to the type of sensor 2 which is connected.

[0072] Finally, the unit 35 has a timer circuit 88 capable of generating the timings required to synchronize the operations which contribute to the measurement of the internal resistance RPVS. This circuit 88 receives at its inputs both the clock signal BT from the circuit 41 (Figure 4) and the command, using the signals SPI, for enabling the measurement of the resistance RPVS.

[0073] The circuit 88 is capable of operating the circuit 87 to regulate the timing of the supply of the reference current to the cell 12, and is also capable of operating the sampling circuits 86 and 63, by means of corresponding signals SH and OL indicating the sampling instants.

[0074] In use, the operating unit 10 operates the timer circuit 88 to enable the measurement of the internal resistance RPVS. First, the unit 10 causes the voltage DVS at the terminals of the cell 12 to be acquired. Then the circuit 88 operates the sampling circuit 63 by means of the signal OL so that the output parameter VAD of the control unit 32 is stored. The circuit 88 then enables the current generator circuit 87 to operate in such a way that the reference current is sent to the sensing cell 12, thus perturbing the state of the cell 12. When this has been done, the voltage at the terminals of the sensing cell 12, due additionally to the reference current, are present at the terminals of the amplifier 85. Finally, the timer circuit 88 operates the sampling circuit 87 to "freeze" the am-

ple, approximately 780°C) during the operation of the engine.

[0090] The control device illustrated above has considerable advantages compared to the known control devices. In the first place, the control device 1 can be used to control sensors 2 of different types, and generates an output signal VOUT which is independent of the variations of the compensating resistance 25.

[0091] Secondly, the programmability of the unit 34 for generating the signal DIP makes it possible to generate an output signal representing the variations of the ratio of the exhaust gases within a programmable and modifiable range of values. On the other hand, every known type of controller provides output signals representing the ratio X of the exhaust gases solely within a single specified range of values, for example $\lambda \in (0.7, 1.2)$, while it does not provide significant information outside this range.

[0092] Moreover, the programmability of the unit 35 for measuring the internal resistance RPVS makes it possible to measure this internal resistance RPVS with both types of sensor, which, as is known, require different reference currents in their sensing cells 12.

Claims

1. Control device (1) for a linear oxygen sensor (2) capable of being located in an exhaust pipe (3) of an internal combustion engine (4), the control device (1) comprising a controller (8) of the sensor (2) capable of exerting a control action on the sensor (2) to generate at the output a signal (DIP) representing the ratio of the exhaust gases; the sensor (2) comprising at least one reference chamber (14) capable of receiving a specified percentage of oxygen, and being of one of at least two types (2a, 2b) which differ in the way in which the reference chamber (14) receives the oxygen; and the control device (1) being characterized in that the controller (8) comprises programmable control means (31, 32, 33, 34, 35, 36) and in that it comprises an operating unit (10) capable of operating and programming the said control means (31, 32, 33, 34, 35, 36) to match the controller (8) to the type of sensor (2a, 2b) to which it is connected.

2. Control device according to Claim 1, in which the sensor (2) comprises a diffusion chamber (13) capable of receiving the exhaust gases and a first (11) and a second (12) electrolytic cell sensitive to oxygen ions, the first of these cells (11) being controllable with respect to current; the said control means (31, 32, 33, 34, 35, 36) comprising a feedback circuit (32, 33, 34) capable of regulating the current (Ip) sent to the first cell (11) in accordance with the difference between the percentages of oxygen present in the diffusion chamber (13) and in the reference chamber (14); the said feedback circuit (32, 33, 34) comprising means (34) of generating the said output signal (DIP), capable of generating the output signal (DIP) in accordance with the current (Ip) sent to the first cell (11); the controller (8) being connected to a compensating resistance (25) capable of compensating the losses of the said sent current (Ip), and comprising an acquisition circuit (36) capable of acquiring the value (RCOMP; RCOMPDIFF) of the compensating resistance (25); the operating unit (10) being capable of correcting the output signal (DIP) of the controller (8) in accordance with the acquired value (RCOMP; RCOMPDIFF) of the compensating resistance (25), to generate a corresponding output signal (VOUT) which is truly representative of the ratio of the exhaust gases and which is independent of possible changes in the compensating resistance (25).

3. Control device according to Claim 2, in which the said programmable control means (31, 32, 33, 34, 35, 36) comprise means (31) for polarizing the second cell (12), which can be activated selectively by the said operating unit (10) according to the type of sensor (2a, 2b) which is connected to the controller (8); the said polarizing means (31) being capable of polarizing the second cell (12) to produce the oxygen in the reference chamber (14).

4. Control device according to Claim 3, in which the said polarizing means (31) comprise at least one polarization current generator (50) connected to the said second cell (12), and switch means (52) interposed between the said polarization current generator (50) and the said second cell (12) to enable the polarization current to be sent in a selective way to the second cell (12).

5. Control device according to any of Claims 2 to 4, in which the said means (31) of generating the output signal (DIP) of the controller (8) are programmable by the operating unit (10) in such a way that the output signal (DIP) indicates the variation of the ratio of the exhaust gases within a range of values which is programmable and can be modified as desired.

6. Control device according to any of Claims 2 to 5, in which the said sensor (2) is capable of generating a first signal (Vd) representing the said difference between the percentages of oxygen present in the diffusion chamber (13) and in the reference chamber (14), the said feedback circuit (32, 33, 34) comprising:

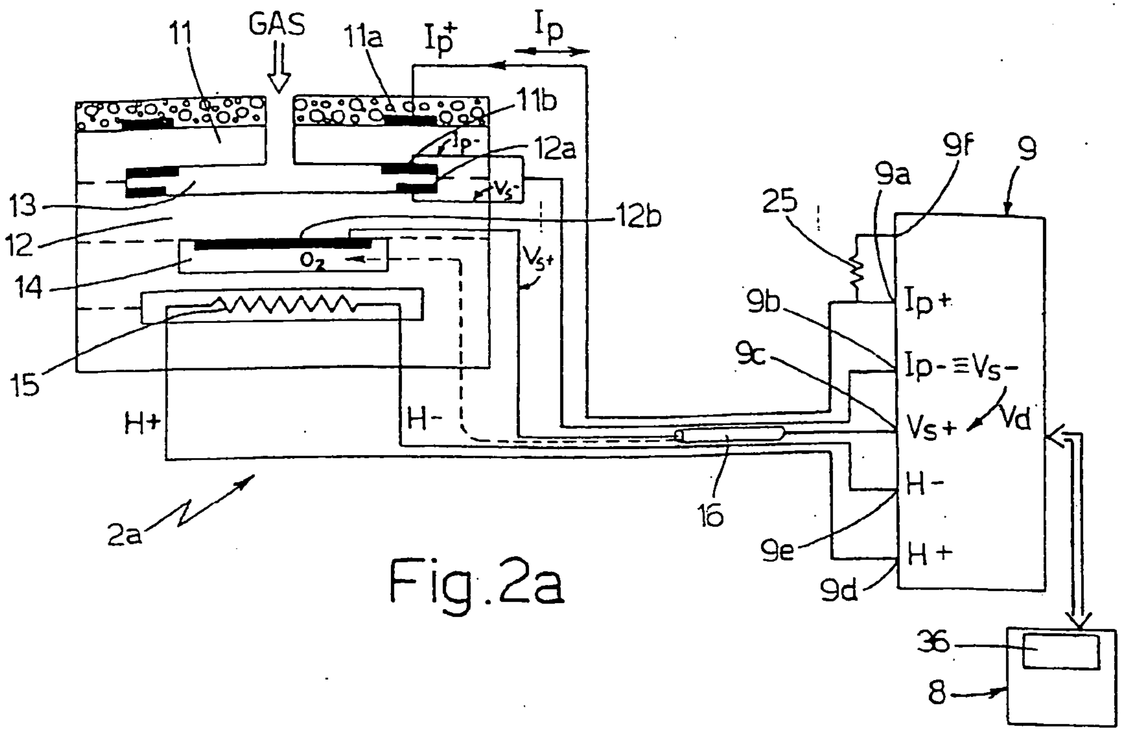
   - processing means (32) receiving the said first signal (Vd) and capable of processing it to generate at the output a parameter (VAD) which identifies the said driving current (Ip) of the first

(9) through which it is connected to the said controller (8); the said compensating resistance (25) being connected between two terminals of the connector (9) in two different ways according to the type of sensor (2a, 2b) which is connected to the controller (8); in the first way, corresponding to a first type of sensor (2a), the compensating resistance (25) is connected between a first (9f) and a second (9a) terminal, while in the second way, corresponding to the second type of sensor (2b), the compensating resistance (25) is connected between the said first terminal (9f) and a third terminal (9d) of the connector (9); the said acquisition circuit (36) comprising first (90, 91) and second (93) means of acquiring the value (RCOMP; RCOMPDIFF) of the compensating resistance (25), which are capable of acquiring the value (RCOMP; RCOMPDIFF) of the compensating resistance (25), if this resistance is connected to the connector (9) in the first way or in the second way respectively.

18. Control device according to Claim 17, in which the said first means of acquisition (90, 91) comprise a current generator circuit (90) connected to the said second terminal (9a) and capable of being operated by the operating unit (10) to send a predetermined current to the compensating resistance (25); the said first means of acquisition (90, 91) also comprising a differential amplifier (91) whose inputs are connected to the first (9f) and second (9a) terminal to amplify the voltage at the terminals of the compensating resistance (25) and to supply at the output a first voltage signal (RCOMPDIFF) indicating the value of the compensating resistance (25).

19. Control device according to Claim 17, in which the said second means of acquisition (93) comprise means of supplying a reference voltage (VBAT) to the said third terminal (9d), and a voltage divider (93) connected to the said first terminal (9f) and generating at its output a second voltage signal (RCOMP) indicating the value of the compensating resistance (25).

20. Control device according to any of Claims 2 to 19, in which the said operating unit (10) comprises a memory unit (94) capable of permanently storing the value (RCOMP; RCOMPDIFF) of the compensating resistance (25); the said memory unit (94) being capable of storing the value (RCOMP; RCOMPDIFF) of the compensating resistance (25) when the engine (3) is started.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9f
9
Ip+
9b
Ip- ≡Vs-
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H-
16
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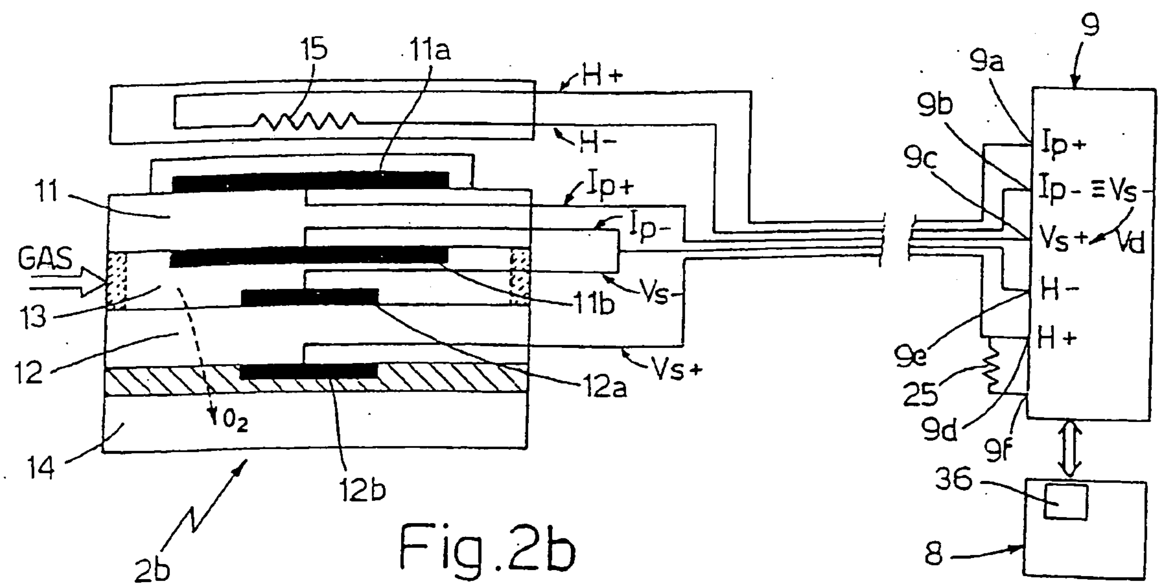
9e
H+
9d
36
8

Fig.2a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Ip+
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Vs-
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12a
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O2
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2b
9
9a
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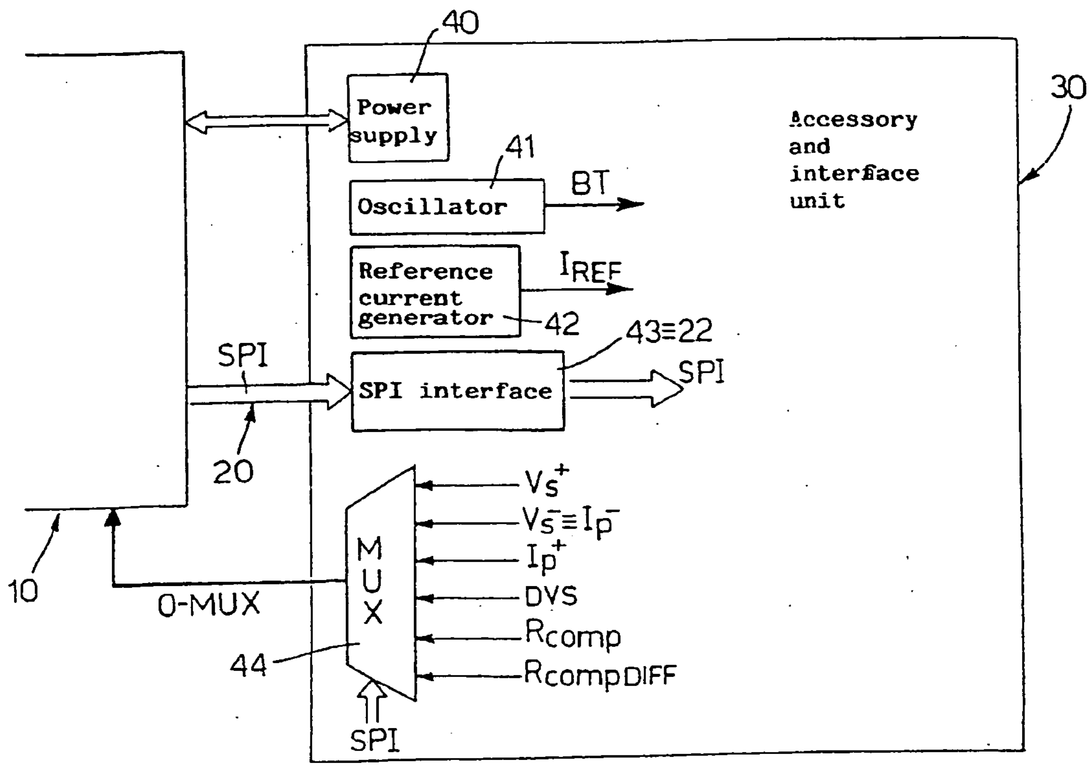
9f
36
8

Fig.2b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Accessory and interface unit
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Oscillator
BT
Reference current generator
IREF
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SPI
SPI interface
SPI
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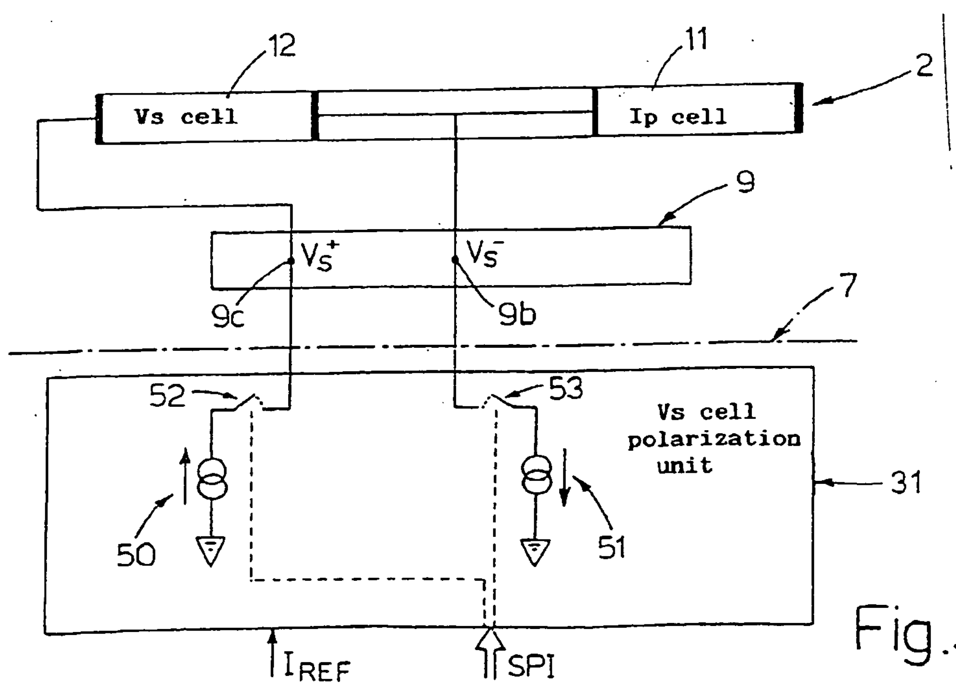
Vs-≡Ip-
Ip+
DVS
Rcomp
RcompDIFF
MUX
10
0-MUX
44
SPI

Fig.4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11
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Vs cell
Ip cell
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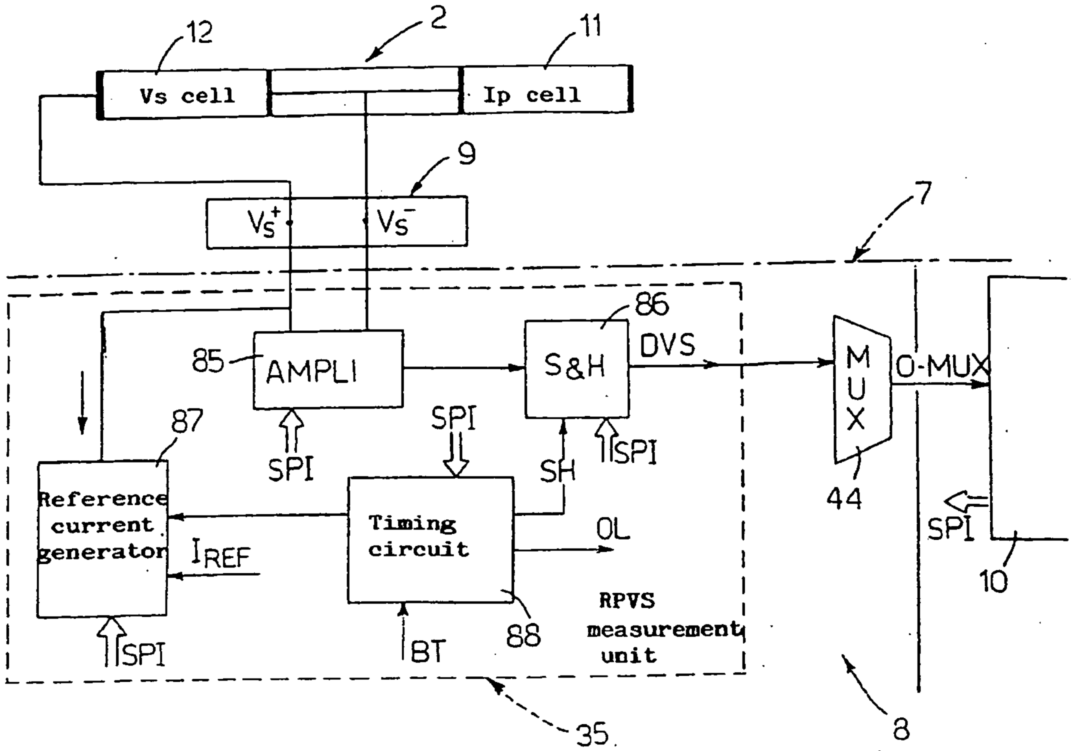
Vs+
Vs-
9c
9b
7
52
53
Vs cell polarization unit
31
50
51
IREF
SPI

Fig.5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2
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Ip cell
9
Vs+
Vs-
7
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DVS
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AMPLI
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M
U
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O-MUX
87
SPI
SPI
SPI
SH
SPI
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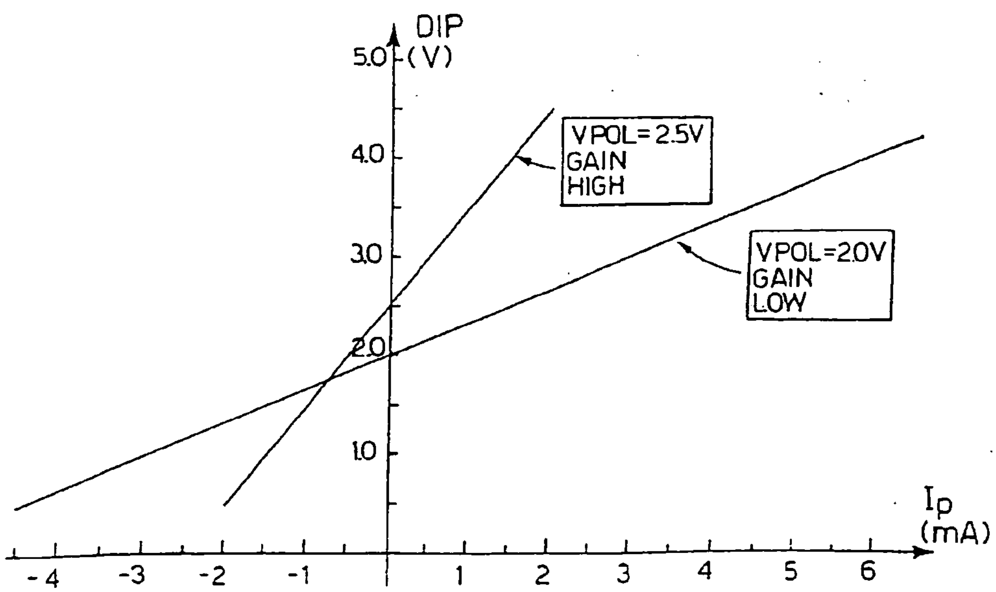
Reference current generator
Timing circuit
OL
SPI
I REF
10
SPI
BT
88
RPVS measurement unit
35
8

Fig.8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5.0
4.0
3.0
2.0
1.0
VPOL=2.5V GAIN HIGH
VPOL=2.0V GAIN LOW
Ip (mA)
-4
-3
-2
-1
1
2
3
4
5
6

Fig.7

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 99 12 2589

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	US 4 276 600 A (HARTFORD ET AL.) 30 June 1981 (1981-06-30) * abstract * * column 2, line 7 - line 49; figure 2 *	1-20	G01N27/406
A	US 4 651 699 A (OHTAKI ET AL.) 24 March 1987 (1987-03-24) * abstract * * column 2, line 33 - column 3, line 20; figure 2 *	1-20	
A	EP 0 507 149 A (MITSUBISHI) 7 October 1992 (1992-10-07) * abstract * * column 7, line 40 - column 9, line 54; figure 2 *	1-20	
			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
			G01N

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	29 February 2000	Kempf, G

CATEGORY OF CITED DOCUMENTS

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Y : particularly relevant if combined with another document of the same category
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E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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